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ALPINE VASCULAR FLORA OF THE TUSHAR MOUNTAINS, UTAH

Alan C. Taye[1]

ABSTRACT.—The Tushar Mountains of southwestern Utah rise to a maximum elevation of 3709 m, with timberline and krummholz reaching maximum elevations of 3438 m and 3566 m, respectively. Voucher specimens were collected from the alpine region during eight field seasons to inventory this largely unknown alpine flora. Listed are 171 vascular plant species from 102 genera and 34 families that occur in eight types of plant communities within an alpine area of about 19.3 km^2. The seven largest families are Asteraceae (29 species), Poaceae (20), Brassicaceae (13), Rosaceae (12), Cyperaceae (11), Caryophyllaceae (10), and Fabaceae (8). Thirteen species are restricted to the alpine area. The perennial herb growth form accounts for 86.4% of the flora, 5.9% of the species are shrubs, and the remaining species are annuals to short-lived perennials. Bedrock in the alpine region is entirely of Tertiary igneous origin. Vegetation cover and species richness are highest on an andesite ash-flow tuff and latite flow and lowest on hydrothermally altered intercaldera rhyolites and tuffs. Forty-four species (26.0% of the indigenous flora) also occur in the Arctic, and 13 species are at a southern margin of distribution. Eight taxa (4.7% of the flora) are local or regional endemics. The majority of the alpine species appear to have migrated to the range by way of the contiguous mountain system to the north; statistical comparison with neighboring alpine floras shows the flora to be most similar to the floras of the Wasatch Mountains, Uinta Mountains, and Teton Range, with Sorensen's similarity indices of 52.8, 50.2, and 48.8% respectively.

Key words: Utah, Colorado Plateau, Tushar Mountains, alpine vascular flora, alpine vegetation, plant geography.

The Tushar Mountains, located in southwestern Utah in the High Plateaus section of the Colorado Plateau at the eastern margin of the Great Basin (Fig. 1), reach a maximum elevation of 3709 m at the summit of Delano Peak. This elevation is surpassed within the state only by peaks in the Uinta Mountains and La Sal Mountains. A diverse alpine environment and flora occur on the 11 peaks that rise above the elevation of timberline. The alpine area is isolated. Though minor patches of alpine vegetation occur on the Fish Lake Plateau 66 km to the northeast and Markagunt Plateau 81 km to the south, the nearest extensive alpine area occurs in the Wasatch Mountains (Mount Nebo) 157 km to the north. The purposes of this paper are to document this isolated alpine flora, briefly describe the alpine plant communities, and determine possible migrational pathways to the Tushars by means of statistical and qualitative comparisons with neighboring alpine areas.

STUDY AREA

The Tushar Mountains have a length of 60 km and a width of 36 km at the widest point. Vertical relief exceeds 2000 m, with a low elevation of 1695 m at the confluence of Clear Creek and the Sevier River. The range is located within an area of large-volume Tertiary (Oligocene to Miocene) volcanic activity known as the Marysvale volcanic field and is composed mostly of volcanic rocks (Cunningham and Steven 1979). Structurally, the range consists of a plateau-like, north-trending, up-faulted block bordered by structural valleys formed from down-faulted blocks; the High Plateaus section is thus structurally transitional between the Basin and Range Province and the Colorado Plateau Province (Hunt 1987). The major faulting that produced the current linear ranges of the High Plateaus occured between 8 million and 5 million years ago (Steven et al. 1984).

Topography and soil development in the alpine area are strongly influenced by the two volcanic formations exposed near timberline and above (Fig. 2). The mostly plateau-like to domelike ridges in the southern and eastern portions of the alpine region (including Delano Peak) are composed of calc-alkaline basaltic andesite flows and tuffs of the Bullion Canyon Volcanics (Cunningham et al. 1983) on which two soil complexes consisting of mollic cryoborolls, argic pachic cryoborolls, pachic

[1]465 North 300 West #22. Provo, UT 84601.

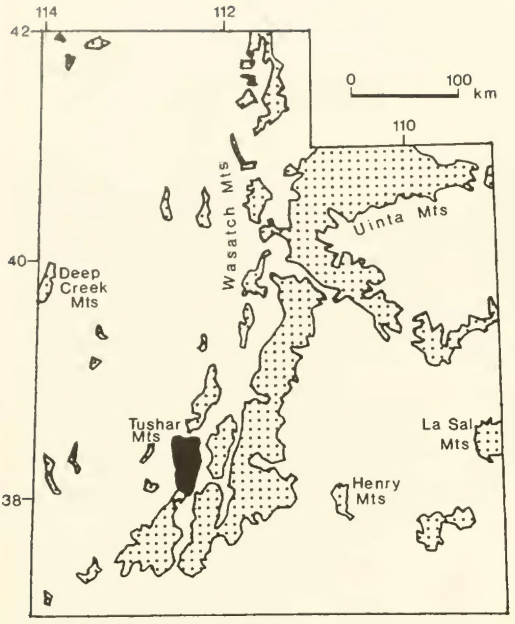

Fig. 1. Map of Utah showing location of Tushar Mountains (in black) and other mountainous areas above 2286 m in elevation (generalized and adapted from Smouse and Gurgel [1981]).

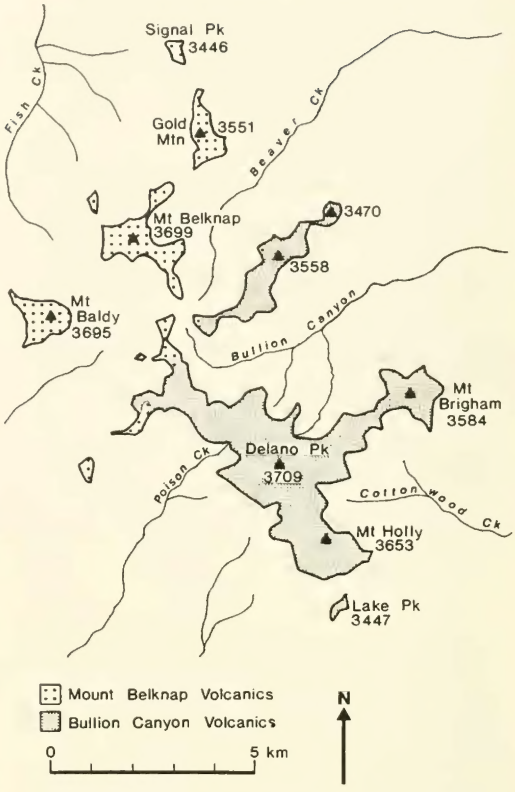

Fig. 2. Map of the central Tushar Mountains with outlined portions approximating the areas above 3383 m in elevation. Location of igneous formations is generalized from Cunningham et al. (1983).

cryoborolls, lithic cryoborolls, and rock outcrops are recognized (U.S. Forest Service 1993).

The more mountainous northern and western portions of the alpine region are composed of intercaldera siliceous alkali rhyolite lava flows, lava domes, and ash-flow tuffs of the Mount Belknap Volcanics which have been hydrothermally altered in many places (Cunningham and Steven 1979) and which are resistant to weathering. The summit pyramids of Mount Belknap (3699 m) and Mount Baldy (3695 m) consist of steep talus slopes and cliffs; portions of these talus slopes lack a cliff at their head and thus appear by definition (Washburn 1979) to be block slopes formed from periglacial frost action. Soil development in this region is limited to areas too small to map, and all alpine exposures of this formation as mapped by Cunningham et al. (1983) are classified by soil scientists as a cirqueland-rubbleland-rock outcrop complex (U.S. Forest Service 1993).

Pleistocene glaciers produced several well-defined cirques on the eastern side of the crest where glacial ice descended to a low elevation of about 2500 m (Callaghan 1973). Glaciation also occurred on the western side of the crest as evidenced by glacial striations in the Poison Creek drainage. Periglacial patterned ground in the form of stone stripes, stone circles, and stone nets occurs on the main ridgecrest between the elevations of 3432 and 3600 m.

Climate of the Rocky Mountain alpine zone is characterized by Billings (1988) to have a mean temperature of less than 10°C for the warmest month. Climatic data are unavailable for the alpine area in the Tushar Mountains. A weather station located in an Engelmann spruce (*Picea engelmannii*) community 3.6 km south of the alpine region at an elevation of 3136 m has a mean annual temperature of 1.7°C, the warmest months being June, July, and August with mean monthly temperatures of 9.2, 11.7, and 10.9°C, respectively (three years of records). Most of the mean annual precipitation of 909 mm (12 years of records) falls as snow. Rainfall from summer thunderstorms is highest in August, with an average of 74 mm, while the months of June and July receive averages

of 46 and 45 mm, respectively (Soil Conservation Service 1993).

An alpine region is defined by Bliss (1985) to be the area above the climatic limit of upright tree growth, although it may include patches of krummholz. The average elevation of timberline in the Tushar Mountains occurs at about 3383 m (11,100 ft), with a corresponding alpine area of about 19.3 km^2 above this elevation. This alpine area, located between 38°20′04″ and 38°27′47″ North latitude and 112°19′32″ and 112°26′42″ West longitude, extends from Signal Peak in the north to Lake Peak at the south over a distance of 14.5 km. Much of the alpine area, centered about 25 km ENE of the city of Beaver, is accessible by Forest Service road 123, which crosses the crest of the range at an elevation of 3505 m.

Timberline coincides with the upper limit of continuous forest and reaches a maximum elevation of 3438 m on a minor ridgecrest on the western (windward) side of the range. Timberline occurs as low as 3341 m on lower ridges and is edaphically depressed even lower on some talus slopes. Engelmann spruce and limber pine (*Pinus flexilis*) are the only arboreal species found at timberline. Subalpine fir (*Abies lasiocarpa*) and aspen (*Populus tremuloides*) approach timberline with maximum known elevations of 3365 and 3292 m, respectively. The krummholz limit, consisting of Engelmann spruce, occurs at about 3566 m on the steep, south-facing slope of Mount Baldy; this slope is protected from prevailing winds by a ridge extending southwesterly from the summit.

METHODS

Voucher specimens were collected from 1984 through 1993 from throughout the range in preparation of a checklist of the vascular plants of the Tushar Mountains. Collected specimens were deposited in the herbarium of Brigham Young University and a search was made in this herbarium for other pertinent specimens. The total known flora for the range consists of 971 taxa representing 924 species, 381 genera, and 89 families (Taye 1994). The alpine region was visited during the same period except for the years 1986 and 1989. Only those species found above local timberline are included in this study.

Species nomenclature and life form classification follow Welsh et al. (1993).

Sorensen's Index of Similarity (Mueller-Dombois and Ellenberg 1974) was used to compare the alpine flora with neighboring alpine floras to determine possible migrational pathways to the Tushars. Differences in nomenclature among the floras were largely resolved with the references of Dorn (1988), Weber and Wittmann (1992), and Welsh et al. (1993). Subspecific taxa were not used in statistical comparisons.

ALPINE VEGETATION

Eight types of alpine plant communities were recognized based on qualitative observations; future intensive study of the vegetation will likely expand this classification. As noted for alpine communities in the Uinta Mountains (Lewis 1970), boundaries between plant communities are usually diffused.

CUSHION PLANT.—Low-growing species dominate the windswept ridgecrests where soils are shallow and outcrops of bedrock and rubble formed in place by frost-heaving are common. Dominant species include *Carex elynoides*, *Cerastium beeringianum*, *Erigeron compositus*, *Festuca ovina*, *Geum rossii*, *Phlox pulvinata*, and *Silene acaulis*.

DRY MEADOW.—The warmer and drier south- and west-facing slopes are characterized by a plant cover in which bare soil is generally present between individual plants; rock cover is frequently high and soil disturbance from pocket gophers is common. Spruce krummholz is common at lower elevations. Common species in this extensive community type include *Achillea millefolium*, *Astragalus miser*, *Carex elynoides*, *Castilleja parvula*, *Cymopterus lemmonii*, *Elymus trachycaulus*, *Haplopappus macronema*, *Helenium hoopsii*, *Phlox pulvinata*, *Potentilla glandulosa*, *P. gracilis*, *Poa secunda*, and *Ribes montigenum*. *Geum rossii* occurs occasionally in usually mesic microhabitats. Alpine populations of *Gentiana parryi*, *Juniperus communis*, *Sambucus racemosa*, *Thalictrum fendleri*, and *Viola nuttallii* occur only in this community type at low elevations.

MESIC MEADOW.—Plant cover is generally higher on suitable (nontalus or bedrock) north- and east-facing slopes and near drainage bottoms and is occasionally carpet-like where sufficient soil development has occurred. Alpine avens (*Geum rossii*) is perhaps the most common species in this community. Komarkova

(1979) found this species to be most abundant on slopes with deep soil profiles and moderately prolonged snow cover. Other common species in this extensive community type include *Arenaria obtusiloba*, *Artemisia scopulorum*, *Carex heteroneura*, *Cerastium beeringianum*, *Erigeron simplex*, *Luzula spicata*, *Pedicularis parryi*, *Phlox pulvinata*, *Poa reflexa*, *Polygonum bistortoides*, *Salix arctica*, *Saxifraga rhomboidea*, and *Silene acaulis*.

WET MEADOW.—A few wet meadows occur adjacent to rivulets and below long-lasting snowdrifts. Common species include *Geum rossii*, *Polygonum bistortoides*, and *Primula parryi*. *Caltha leptosepala*, *Potentilla diversifolia*, *Sedum rhodanthum*, and *Stellaria longipes* reach their upper elevational limit of 3627 m in this community type on the north-facing slope of Delano Peak.

RIVULET.—Alpine rivulets from melting snowfields are mostly transitory and occur only in the southern (Bullion Canyon Volcanics) portion of the alpine region. *Cardamine cordifolia*, *Deschampsia cespitosa*, *Delphinium occidentale* var. *barbeyi*, and *Mertensia arizonica* occur at lower elevations while *Caltha leptosepala*, *Pedicularis parryi*, and *Salix arctica* occur more commonly at higher elevations. *Polygonum bistortoides* and *Primula parryi* are common throughout this community type. Two rivulets on the flanks of Delano Peak (to about 3444 m in elevation) persist throughout the summer; *Epilobium halleanum*, *Juncus drummondii*, *Mimulus tilingii*, and *Saxifraga odontoloma* occur at their upper elevational limit at these continually moist and marginally alpine sites.

GRAVELLY BARREN.—This is perhaps the most distinctive alpine community type in the Tushar Mountains. It occurs on saddles of ridgecrests and on many of the higher tributary drainages between Lake Peak and Mount Belknap where snow accumulations are long lasting; plant cover is only 0 to about 20% on largely unaltered, gravelly, grayish parent material. Some of the relatively few species that occur here are *Calyptridium umbellatum*, *Elymus scribneri*, *Ivesia gordonii*, *Phlox pulvinata*, *Polemonium viscosum*, *Senecio amplectens*, and *S. canus*. The endemic *Draba sobolifera* frequently flowers in gravel at the edge of receding snowbanks. Isolated 'hanging' patches of *Geum rossii* turf are sometimes present, indicating possible recent erosion of surrounding material. Gravelly barrens usually intergrade into dry meadow or talus/scree communities over relatively short distances.

BEDROCK.—Plant growth on exposures of bedrock is restricted to rock crevices and ledges where pockets of soil have accumulated. Species present include many of those present on similar aspects in surrounding dry and mesic meadow communities. A unique assemblage of species that occasionally occurs on north-facing exposures includes *Artemisia scopulorum*, *Carex heteroneura*, *Cystopteris fragilis*, *Erigeron compositus*, *Geum rossii*, *Oxyria digyna*, *Saxifraga caespitosa*, *S. debilis*, and *Stellaria longipes*.

TALUS/SCREE.—Colluvial deposits are most common in the area composed of the Mount Belknap Volcanics and along the glaciated portions of the main ridgecrest. *Arenaria nuttallii*, *Cerastium beeringianum*, *Erigeron compositus*, and *Polemonium viscosum* are commonly present on all exposures while *Artemisia scopulorum*, *Geum rossii*, and *Primula parryi* are more common on more mesic north- and east-facing slopes within this community type.

THE FLORA

The alpine flora of the Tushar Mountains consists of 171 species from 102 genera and 34 families. The largest families are Asteraceae (29 species), Poaceae (20), Brassicaceae (13), Rosaceae (12), Cyperaceae (11), Caryophyllaceae (10), Fabaceae (8), Ranunculaceae (7), and Scrophulariaceae (7). The largest genera are *Carex*, *Poa*, and *Potentilla* with 11, 8, and 7 species, respectively, while *Saxifraga* and *Senecio* are each represented by five species. *Bromus inermis* and *Taraxacum officinale* are the only introduced species occurring above timberline. The species list is presented near the end of this paper.

Thirteen taxa appear to be restricted to the alpine area: *Astragalus australis* var. *glabriusculus*, *Carex elynoides*, *C. haydeniana*, *C. nardina*, *Claytonia megarhiza*, *Hymenoxys grandiflora*, *Lychnis apetala* var. *kingii*, *Poa pattersonii*, *Potentilla concinna*, *Salix arctica*, *Saxifraga caespitosa*, *Townsendia condensata*, and *Valeriana acutiloba*.

Three taxa (1.8% of the alpine flora) are endemic to high elevations in the Tushar Mountains. *Draba sobolifera* and *Senecio castoreus* are most common in gravelly barren and talus/

scree communities above timberline while *Cirsium eatonii* var. *harrisonii* is most common on subalpine talus/scree slopes. Other Utah endemics found in the alpine are *Agoseris glauca* var. *cronquistii*, *Astragalus perianus*, *Castilleja parvula* var. *parvula*, *Gilia tridactyla*, and *Lesquerella wardii*.

The perennial herb life form accounts for 86.4% of the indigenous alpine flora. This figure includes 143 species of angiosperms (110 dicots and 33 monocots), one spikemoss, and two ferns. Ten species of shrubs (5.9% of the flora) are present (two of which are gymnosperms). The remaining 13 indigenous taxa are considered to be annual or biennial to short-lived perennials. Only 1.8% of the flora (*Chenopodium atrovirens*, *Gentianella tenella*, and *Polygonum douglasii*) is classified as strictly annual though Spira (1987) reports *Gentianella tenella* to be strictly biennial in the alpine of the White Mountains, CA. Perennial herbs increase in importance at higher elevations and comprise 94.6% of the species (53 of 56 taxa—with exceptions being *Androsace septentrionalis*, *Draba crassifolia*, and *Salix arctica*) known to occur in the area of 0.6 km^2 above the elevation of 3596 m on Delano Peak. A similar life form composition is reported for the alpine flora of the Teton Range (Spence and Shaw 1981).

Species richness and habitat diversity are greatest in the vicinity of Delano Peak because of this peak's geologic substrate, glacial history, and elevation. Erosion of the Bullion Canyon Volcanics has produced a mostly plateau-like topography conducive to soil formation and associated meadow communities. The northern and eastern slopes of Delano Peak, though glaciated, are relatively gentle as compared to the cliff-like glacial headwalls present along much of the main ridgecrest; persistent snowdrifts (sometimes lasting throughout the summer), which are necessary for the growth of some alpine species (Billings 1978) and which provide moisture to lower elevations, are thus able to form on these less-insolated, high-elevation, leeward slopes. All eight types of plant communities and a minimum of 101 species (59.8% of the indigenous alpine flora) are known to occur within a radius of 1.0 km of the summit within an area of 3.14 km^2 (16.3% of the alpine area).

The northern portion of the alpine region composed of the weathering-resistant Mount Belknap Volcanics is floristically poor despite the presence of the second and third highest peaks; no vascular plants were observed above the elevation of 3536 m on Mount Belknap. A depauperate alpine flora of about 65 species occurs on the ridgecrest cushion plant communities, block slopes, and in the talus/scree and gravelly barren communities and small patches of mesic meadow that occur on the ridges and flanks of these summits; *Cryptogramma crispa* and *Poa pattersonii* apparently occur in the alpine only on this formation, however. Soil formation and plant growth on this substrate may be hindered by unfavorable nutrient availability as occurs locally in hydrothermally altered, highly acidic exposures at the base of the range (Salisbury 1964).

PLANT GEOGRAPHY

The Tushar Mountains are located on the western margin of a floristically similar highland region known as the Southern Rocky Mountains. This area, which includes most of Colorado and parts of adjacent states, contains the greatest concentration of alpine tundra in the United States outside of Alaska (Weber 1965). One hundred fifty-five of the 169 indigenous alpine species of the Tushar Mountains are also reported by Weber and Wittmann (1992) for the flora of Colorado.

Statistical comparison with 14 neighboring alpine floras shows the Tushar alpine flora to be most similar to the adjacent northerly floras of the Wasatch and Uinta ranges of Utah and the Teton Range, Wyoming, with Sorensen's similarity indices of 52.8, 50.2, and 48.8%, respectively (Table 1). The relatively continuous "Teton-Wasatch-High Plateau mainland mountain system" (Harper et al. 1978), which is perhaps best illustrated as an elevated (2000 m and higher elevation) corridor in Figure 19 in Reveal (1979) over which direct migration of alpine species may have occurred during glacial times (Billings 1978) and which has previously been noted to be a migration route for Utah's boreal species (Harper et al. 1978, Welsh 1978, Reveal 1979, and Welsh 1993), has thus likely been a primary source area for development of the alpine flora of the Tushar Mountains. In particular, *Calyptridium umbellatum*, *Cymopterus hendersonii*, *Synthris pinnatifida*, and *Townsendia condensata* appear to have migrated to the Tushars via this north-to-

TABLE 1. Floristic similarity indices between the alpine flora of the Tushar Mountains, UT, and representative neighboring alpine floras. The index of similarity used is that of Sorensen (Mueller-Dombois and Ellenberg 1974). Mainland area floras are part of a relatively continuous mountain system such as the Teton-Wasatch-High Plateau system in contrast to the more isolated mountain floras of the Great Basin and portions of the Colorado Plateau (Harper et al. 1978).

Flora[a]	Number of indigenous alpine species	Alpine-to-alpine distance from Tushar Mts (km)	Percent similarity
MAINLAND AREAS			
1. Wasatch Mountains, UT	202	157	52.8
2. Uinta Mountains, UT	257	269	50.2
3. San Juan Mountains, CO	250	410	44.9
4. Sawatch Range, CO	285	507	45.4
5. Teton Range, WY	216	573	48.8
6. Indian Peaks area, CO	249	596	42.1
7. Pioneer Mountains, ID	130	600	36.8
8. Sangre de Cristo Mountains, NM	157	627	40.5
9. Beartooth Plateau, WY-MT	185	750	36.2
MOUNTAIN ISLANDS			
10. Henry Mountains, UT	47	136	32.4
11. Snake Range, NV	43	171	25.5
12. Deep Creek Mountains, UT	81	198	51.2
13. San Francisco Peaks, AZ	82	332	44.6
14. Ruby Mountains, NV	150	345	42.0

[a]Alpine floras are from the following sources: (1) Arnow et al. (1980) and voucher specimens from Allred (1975) and Collins (1980); (2) Lewis (1970), Goodrich and Neese (1986), and Goodrich (1994); (3) Webber et al. (1976) and Hartman and Rottman (1985); (4) Hartman and Rottman (1988); (5) Spence and Shaw (1981); (6) Komarkova (1979); (7) Moseley and Bernatas (1992); (8) Baker (1983); (9) Johnson and Billings (1962); (10) Neese (1981); (11) Lewis (1973); (12) McMillan (1948); (13) Schaack (1983) and Schaack and Morefield (1985); (14) Loope (1969) and Lewis (1971).

south route, inasmuch as they occur in western Wyoming (Dorn 1988) but are unreported from Colorado (Weber and Wittmann 1992). A total of 158 of the indigenous Tushar alpine species are reported by Dorn (1988) for the flora of Wyoming. The alpine flora of the Tushar Mountains is more similar to that of the Teton Range, Wyoming, than to any of the compared Colorado alpine floras despite a greater distance of up to 160 km (Table 1). Proximity along the same migrational pathway thus appears to be an important factor in floristic similarity.

The apparent effectiveness of the Teton-Wasatch-High Plateau migration route is further illustrated by 13 boreal species occurring in the alpine of the Tushars which are apparently at a southern margin of distribution within the longitudes of Utah: *Astragalus australis*, *Carex nardina*, *Lychnis apetala*, and *Salix arctica* are arctic species (Polunin 1959) not known to occur further south in Utah (Albee et al. 1988) or in adjacent Arizona (Lehr 1978). A total of 44 alpine species from the Tushars (26.0% of the indigenous alpine flora) are reported by Polunin (1959) as also occurring in the Arctic. Other alpine species at an apparent southern margin of distribution are *Antennaria alpina* var. *media*, *Arenaria nuttallii*, *Calyptridium umbellatum*, *Chamaerhodos erecta*, *Claytonia megarhiza*, *Hymenoxys grandiflora*, *Poa pattersonii*, *Saxifraga adscendens*, and *Townsendia condensata*. Nonalpine boreal species at a southern margin of distribution in this range include *Arnica diversifolia*, *Aster engelmannii*, *Carex deweyana*, *C. hoodii*, *C. luzulina*, *Draba lanceolata*, *Hieracium gracile*, *Leucopoa kingii*, *Microseris nutans*, and *Mitella pentandra*.

Though migration of high-elevation species has occurred between the Colorado Rockies and the La Sal Mountains of southeastern Utah (Holmgren 1972, Welsh 1993), significant migration of alpine species further west to the Tushar Mountains has perhaps been limited by an area of relatively low elevation termed the "Colorado Plateau migrational barrier" by Hadley (1987). The isolated Henry Mountains, located midway between the Tushar and La Sal ranges (Fig. 1), have a meager alpine flora of 47 species; absent there are common alpine species such as *Gentiana rossii*, *Oxyria digyna*, *Polygonum bistortoides*, and *Silene acaulis* (Neese 1981). These and other alpine species may have been eliminated from the Henry Mountains by the warmer post-glacial hypsithermal climate (Neese 1981), however, thus

masking the true effectiveness of the Colorado Plateau as a migrational barrier to high-elevation species.

Species richness, which is strongly correlated with area on mountains (Harper et al. 1978, Hadley 1987), also appears to affect floristic similarity as the Tushar alpine flora generally has higher indices of similarity with the larger and generally more distant mainland floras (Table 1); Harper et al. (1978) note that the isolated mountain floras of the Intermountain West have fewer species per unit area than adjacent mainlands and also an uneven stocking of species as a result of greater randomness of colonization and/or extinction. The isolated alpine floras of the east central Great Basin to the west of the Tushars (Loope 1969), the San Francisco Peaks to the south (Moore 1965), and the Henry Mountains to the east (Neese 1981) are slightly to extremely depauperate examples of the Rocky Mountains alpine flora.

The Tushar alpine flora is also slightly depauperate in comparison with most other neighboring mainland area floras (Table 1); this is likely due to the limited alpine area (in comparison, the Uinta Mountains have an alpine area of about 1000 km^2 [Lewis 1970]), scarcity of wet meadows and rivulets, and presence of the talus-forming Mount Belknap Formation. The smaller Tushar alpine flora may be a factor in the relatively low maximum similarity index of 52.8% with the Wasatch Mountains; Hartmann and Rottman (1988) report a similarity index range of 72.5–73.3% between the larger alpine floras in Colorado.

The alpine flora and vegetation of the Tushar Mountains are remarkably diverse given the relatively small alpine area. Interesting, too, are the number of endemic taxa and species that reach a southern limit of distribution here. The wide-ranging alpine species *Claytonia megarhiza*, *Poa pattersonii*, and *Saxifraga adscendens* are disjunct here with other in-state distributions only in the Uinta and La Sal ranges, while *Townsendia condensata* occurs nowhere else in the state (Albee et al. 1988, Welsh et al. 1993).

Alpine environments are in general fragile and easily susceptible to disturbance (Billings 1973). This fragility is locally compounded by poor soil-forming characteristics of some igneous members and by the questionable introduction of Rocky Mountain goats to the range in 1986. There is evidence these animals feed on the endemic *Castilleja parvula*, and they endanger the species diversity of the alpine area by grazing at scarce alpine wet sites.

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ANNOTATED LIST OF VASCULAR PLANTS

The following list of families, genera, and species is arranged alphabetically within the divisions of Cronquist et al. (1972). Community type(s) and maximum elevation noted for each taxon are based on field notes and herbarium specimen label information. The following abbreviations are used for community types: cushion plant (CP), dry meadow (DM), mesic meadow (MM), wet meadow (WM), rivulet (RI), gravelly barren (GB), bedrock (BR), and talus/scree (TS). Frequency of occurrence for most taxa is estimated using the following scale from Thorne (1967): rare, 1–3 collections or observation stations; infrequent, 4–7 sta-

tions; frequent, 8–12 stations; common, 13+ stations. Life form is listed as a = annual, ab = annual or biennial, ap = annual to short-lived perennial, bp = biennial to perennial, p = perennial herb, and s = shrub. Species that also occur in the Arctic (Polunin 1959) are followed by an asterisk (*).

I collected *Botrychium lunaria*, *Juncus mertensianus*, *Pedicularis groenlandica*, and *Salix planifolia* at a seep below local timberline at an elevation of 3389 m, and *Draba lanceolata* has been collected at timberline (Welsh et al. 14015). These and other taxa may eventually be discovered from the alpine area. *Erigeron humilis* and *Taraxacum ceratophorum* have recently been reported for the Tushars (Cronquist 1994), but I have seen no specimens.

DIVISION LYCOPODIOPHYTA

Selaginellaceae

Selaginella watsonii **Underw.**; rock crevices in CP, DM, MM, BR, and TS to 3658 m; common; p.

DIVISION POLYPODIOPHYTA

Polypodiaceae

Cryptogramma crispa **(L.) R. Br. var. *acrostichoides*** **(R. Br.) C. B. Clarke**; TS to 3304 m; rare; p.

Cystopteris fragilis **(L.) Bernh.**; rock crevices in DM, MM, RI, BR, and TS to 3505 m; frequent; p.*

DIVISION PINOPHYTA

Cupressaceae

Juniperus communis **L. var. *depressa*** **Pursh**; DM at 3444 m in shelter of boulder on south-facing slope; rare; s.*

Pinaceae

Picea engelmannii **Parry**; DM, MM, and TS to 3566 m; common; s.

DIVISION MAGNOLIOPHYTA

CLASS MAGNOLIOPSIDA

Apiaceae

Cymopterus hendersonii **(Coult. & Rose) Cronq.**; CP, BR, and TS to 3627 m; frequent; p.

Cymopterus lemmonii **(Coult. & Rose) Dorn [*Pseudocymopterus montanus* (Gray) Coult. & Rose]**; CP, DM, MM, RI, and TS to 3700 m; common; p.

Asteraceae

Achillea millefolium **L. ssp. *lanulosa*** **(Nutt.) Piper**; DM, MM, and RI to 3548 m; common; p.*

Agoseris aurantiaca **(Hook.) Greene var. *purpurea*** **(Gray) Cronq.**; MM(?) to ca 3505 m; rare; p.

Agoseris glauca **(Pursh) Raf. var. *cronquistii*** **Welsh**; DM to 3353 m; infrequent; p.

Agoseris glauca **(Pursh) Raf. var. *dasycephala*** **(T. & G.) Jepson**; CP to 3414 m; rare; p.

Antennaria alpina **(L.) Gaertner var. *media*** **(Greene) Jepson [*A. media* Greene]**; CP, MM, and BR to 3487 m; common; p.

Antennaria microphylla **Rydb.**; DM to 3536 m; rare; p.

Arnica mollis **Hook.**; BR/MM to 3444 m; rare; p.

Artemisia frigida **Willd.**; CP and DM to 3505 m; rare; s.*

Artemisia ludoviciana **Willd. var. *incompta*** **(Nutt.) Cronq.**; CP, DM, MM, and RI to 3475 m; common; p.

Artemisia scopulorum **Gray**; MM, WM, RI, BR, and TS to 3703 m; common; p.

Cirsium eatonii **(Gray) Robins. var. *harrisonii*** **Welsh**; TS to 3444 m; rare; p.

Crepis nana **Richards.**; CP, GB, and TS to 3475 m; frequent; p.*

Erigeron compositus **Pursh var. *glabratus*** **Macoun**; CP, DM, GB, BR, and TS to 3706 m; common; p.*

Erigeron simplex **Greene**; MM to 3700 m; frequent; p.

Erigeron speciosus **(Lindl.) DC. var. *uintahensis*** **(Cronq.) Welsh [*E. uintahensis* Cronq.]**; DM to 3414 m; rare; p.

Erigeron ursinus **D. C. Eaton**; CP, MM, and RI to 3536 m; common; p.

Haplopappus clementis **(Rydb.) Blake**; MM and GB to 3578 m; common; p.

Haplopappus macronema **Gray**; CP, DM, GB, and TS to 3536 m; common; s.

Helenium hoopesii **Gray [*Dugaldia hoopesii* (Gray) Rydb.]**; DM and MM to 3566 m; common; p.

Hymenopappus filifolius **Hook. var. *nudipes*** **(Maguire) Turner**; DM and GB to 3561 m; infrequent; p.

Hymenoxys grandiflora **(T. & G.) Parker**; "grassy tundra above timberline" at 3505 m; rare; p. The only record from the range is K. F. Parker et al. 6354 at the Rancho Santa Ana Botanic Garden.

Senecio amplectens **Gray var. *holmii*** **(Greene) Harrington**; MM, GB, and BR to 3700 m; common; p.

Senecio canus **Hook.**; DM and GB to 3609 m; common; p.

Senecio castoreus **Welsh**; CP, GB, and TS to 3536 m; infrequent; p.

Senecio eremophilus **Richards. var. *kingii*** **(Rydb.) Greenman**; DM and MM to 3536 m; infrequent; p.

Senecio werneriaefolius **(Gray) Gray**; TS to 3505 m; frequent; p.

Solidago multiradiata **Ait.**; DM, MM, GB, and BR to 3700 m; common; p.*

Solidago parryi **(Gray) Greene [*Haplopappus parryi* Gray]**; MM to 3505 m; infrequent; p.

Taraxacum officinale **Weber**; DM and TS to 3536 m; infrequent; introduced p.

Townsendia condensata **D. C. Eaton**; CP and GB at 3505–3609 m; infrequent; p.

Boraginaceae

Mertensia arizonica **Greene**; DM, MM, and RI to 3505 m; common; p.

Brassicaceae

Arabis drummondii **Gray**; DM to 3414 m; infrequent; bp.

Arabis lemmonii **Wats.**; MM and BR to 3402 m; rare; p.

Cardamine cordifolia **Gray**; RI to 3444 m; infrequent (locally common); p.

Descurainia richardsonii (Sweet) Schulz var. *brevipes* (Nutt.) Welsh & Reveal; RI and TS to 3475 m; infrequent; ab.

Draba aurea Vahl; MM and BR to 3688 m; rare; p.*

Draba crassifolia Graham; MM and RI to 3700 m; frequent; ap.*

Draba sobolifera Rydb.; MM, GB, BR, and TS to 3688 m; common; p.

Draba stenoloba Ledeb.; MM to 3505 m; rare; ap.*

Erysimum asperum (Nutt.) DC.; DM to 3441 m; rare; bp.

Lesquerella wardii Wats.; DM and GB to 3609 m; frequent; p.

Physaria chambersii Rollins var. *chambersii*; GB to 3414 m; rare; p.

Smelowskia calycina C. A. Mey. var. *americana* (Regel & Herder) Drury & Rollins; CP, DM, MM, BR, and TS to 3703 m; common; p.*

Thlaspi montanum L. var. *montanum*; CP, MM, and TS to 3475 m; common; p.

Caprifoliaceae

Sambucus racemosa L. var. *microbotrys* (Rydb.) Kearney & Peebles; DM and TS to 3444 m; infrequent; s.

Caryophyllaceae

Arenaria nuttallii Pax; CP, MM, GB, and TS to 3505 m; common; p.

Arenaria obtusiloba (Rydb.) Fern.; MM and WM to 3676 m; common; p.*

Arenaria rubella (Wahl.) J. E. Sm.; CP, DM, MM, and RI to 3688 m; frequent; p.*

Cerastium beeringianum C. & S.; CP, DM, MM, WM, BR, and TS to 3700 m; common; p.*

Lychnis apetala L. var. *kingii* (Wats.) Welsh [*L. kingii* Wats.]; CP, DM, and MM at 3536–3688 m; frequent; p.*

Lychnis drummondii (Hook.) Wats.; DM, MM, and BR to 3487 m; frequent; p.

Sagina saginoides (L.) Britt.; MM and RI to 3414 m; rare; bp.*

Silene acaulis L. var. *subacaulescens* (F. Williams) Fern. & St. John; CP, MM, WM, BR, and TS to 3676 m; common; p.*

Stellaria longipes Goldie; DM, MM, WM, BR, and TS to 3627 m; common; p.*

Stellaria umbellata Turcz.; MM, RI, and TS to 3615 m; frequent; p.

Chenopodiaceae

Chenopodium atrovirens Rydb.; DM in disturbed soil (pocket gophers?) at 3548 m; rare; a.

Crassulaceae

Sedum rhodanthum Gray; MM and WM to 3627 m; infrequent; p.

Fabaceae

Astragalus australis Fisch. var. *glabriusculus* (Hook.) Isely [*A. aboriginum* Richards.]; CP and GB at 3505–3609 m; infrequent; p.*

Astragalus miser Dougl. var. *oblongifolius* (Rydb.) Cronq.; DM, MM, and GB to 3706 m; common; p.

Astragalus perianus Barneby; DM and GB to 3566 m; infrequent; p.

Lupinus argenteus Pursh var. *rubricaulis* (Greene) Welsh; DM to 3463 m; rare; p.

Lupinus lepidus Dougl. var. *utahensis* (Wats.) C. L. Hitchc. [*L. caespitosus* Nutt. var. *utahensis* (Wats.) B. Cox]; DM, MM, and GB to 3572 m; frequent; p.

Oxytropis oreophila Gray var. *oreophila*; CP, DM, MM, and GB to 3706 m; common; p.

Oxytropis parryi Gray; DM and MM to 3633 m; infrequent; p.

Trifolium longipes Nutt. var. *rusbyi* (Greene) Harrington; MM to 3597 m; frequent; p.

Gentianaceae

Gentiana parryi Engelm.; DM to 3389 m; rare; p.

Gentianella amarella (L.) Borner; DM and MM to 3535 m; frequent; ab.*

Gentianella tenella (Rottb.) Borner; MM and WM to 3566 m; rare; a (b?).*

Swertia radiata (Kellogg) Kuntze [*Frasera speciosa* Dougl.]; MM and TS to 3475 m; rare; p.

Grossulariaceae

Ribes cereum Dougl.; DM and BR to 3536 m; frequent; s.

Ribes inerme Rydb.; DM (among rocks) and TS to 3438 m; rare; s.

Ribes montigenum McClatchie; DM, MM, RI, and TS to 3627 m; common; s.

Hydrophyllaceae

Phacelia hastata Dougl.; DM in gravelly soil to 3444 m; rare; p.

Phacelia sericea (Graham) Gray var. *ciliosa* Rydb.; DM to 3475 m; rare; p.

Lamiaceae

Monardella odoratissima Benth.; TS to 3475 m; rare; p.

Linaceae

Linum perenne L. ssp. *lewisii* (Pursh) Hulten; MM in gravelly soil at 3536 m; rare; p.*

Onagraceae

Epilobium angustifolium L.; TS to 3414 m; rare; p.*

Epilobium halleanum Hausskn.; RI to 3444 m; rare (locally common); p.

Epilobium saximontanum Hausskn.; RI to 3487 m; rare (locally common); p.

Polemoniaceae

Gilia tridactyla Rydb.; CP and TS to 3414 m; rare; p.

Phlox pulvinata (Wherry) Cronq.; CP, DM, MM, GB, BR, and TS to 3706 m; common; p.

Polemonium pulcherrimum Hook. var. *delicatum* (Rydb.) Cronq.; DM and MM to 3444 m; infrequent; p.*

Polemonium viscosum Nutt.; DM, MM, GB, BR, and TS to 3633 m; common; p.

Polygonaceae

Eriogonum umbellatum Torr. var. *porteri* (Small) Stokes; DM, MM, and BR to 3566 m; frequent; p.

Oxyria digyna (L.) Hill; MM, GB, BR, and TS to 3658 m; common; p.*

Polygonum bistortoides Pursh; MM, WM, and RI to 3676 m; common; p.

Polygonum douglasii Greene var. *douglasii*; DM to 3444 m; rare; a.

Rumex salicifolius Weinm. ssp. *triangulivalvis* Danser; DM, MM, RI, and BR to 3499 m; frequent; p.

Portulacaceae

Calyptridium umbellatum (Torr.) Greene var. *caudicifera* Gray; MM and GB to 3536 m; infrequent; ap.

Claytonia megarhiza (Gray) Parry; BR and TS at 3475 to 3615 m; rare; p.

Lewisia pygmaea (Gray) Robins.; MM and RI to 3597 m; frequent; p.

Primulaceae

Androsace septentrionalis L.; DM, MM, RI, and TS to 3700 m; common; ab.*

Primula parryi Gray; MM, WM, RI, BR, and TS to 3658 m; common; p.

Ranunculaceae

Anemone multifida Poir.; CP and MM to 3487 m; rare; p.

Aquilegia scopulorum Tidestr.; TS to 3438 m; infrequent; p. As noted in Welsh et al. (1993), some specimens are completely transitional with *A. caerulea* James.

Caltha leptosepala DC. var. *leptosepala*; MM, WM, and RI to 3627 m; frequent; p.

Delphinium occidentale (Wats.) Wats. var. *barbeyi* (Huth) Welsh [*D. barbeyi* (Huth) Huth]; DM, RI, and TS to 3475 m; common; p.

Ranunculus eschscholtzii Schlect.; TS to ca 3490 m; rare; p.

Ranunculus inamoenus Greene; DM and RI to 3597 m; common; p.

Thalictrum fendleri Engelm.; DM (in shelter of *Ribes montigenum*) to 3414 m; rare; p.

Rosaceae

Chamaerhodos erecta Bunge var. *parviflora* (Nutt.) C. L. Hitchc.; CP and DM to 3505 m; rare; bp.

Geum rossii (R. Br.) Ser. var. *turbinatum* (Rydb.) C. L. Hitchc.; CP, DM, MM, WM, RI, GB, TS, and BR to 3700 m; common; p.*

Ivesia gordonii (Hook.) T. & G.; DM and GB to 3609 m; infrequent; p.

Potentilla concinna Richards. var. *proxima* (Rydb.) Welsh & Johnston; DM and TS at 3353 to 3536 m; infrequent; p.

Potentilla diversifolia Lehm. var. *diversifolia*; WM, RI, and TS to 3627 m; frequent; p.

Potentilla glandulosa Lindl. var. *intermedia* (Rydb.) C. L. Hitchc.; DM, MM, and TS to 3487 m; common; p.

Potentilla gracilis Dougl. var. *pulcherrima* (Lehm.) Fern.; DM to 3463 m; frequent; p.

Potentilla hippiana Lehm.; DM to 3414 m; p.

Potentilla ovina Macoun var. *decurrens* (Wats.) Welsh & Johnston; CP and DM to 3475 m; infrequent; p.

Potentilla pensylvanica L. var. *pensylvanica*; CP, DM, MM, and TS to 3700 m; common; p.*

Rubus idaeus L. ssp. *melanolasius* (Dieck) Focke.; TS to 3414 m; rare; s.

Sibbaldia procumbens L.; MM, RI, and BR to 3627 m; common; p.*

Salicaceae

Salix arctica Pallas var. *petraea* Anderss.; MM, WM, and RI at 3444 to 3676 m; frequent (locally common); s.*

Saxifragaceae

Heuchera rubescens Torr. var. *rubescens*; BR to 3444 m; rare; p.

Saxifraga adscendens L. var. *oregonensis* (Raf.) Breitung; MM (among rocks) to 3676 m; rare; p.

Saxifraga caespitosa L. var. *minima* Blake; MM, WM, and BR at 3566 to 3676 m; infrequent; p.*

Saxifraga debilis Engelm.; MM and BR to 3658 m; common; p.

Saxifraga odontoloma Piper; RI to 3444 m; rare; p.

Saxifraga rhomboidea Greene; DM, MM, WM, and RI to 3700 m; common; p.

Scrophulariaceae

Castilleja miniata Dougl.; DM to 3535 m; infrequent; p.

Castilleja parvula Rydb. var. *parvula*; DM and MM to 3688 m; common; p.

Mimulus tilingii Regel; RI to 3414 m; rare; p.

Pedicularis parryi Gray var. *parryi*; MM, WM, and RI to 3627 m; common; p.

Penstemon whippleanus Gray; MM and BR to 3450 m; frequent; p.

Synthris pinnatifida Wats. var. *laciniata* Gray; DM, MM, WM, RI, and BR to 3627 m; common; p.

Veronica wormskjoldii R. & S.; MM and RI to 3487 m; rare; p.*

Valerianaceae

Valeriana acutiloba Rydb.; DM and MM at 3414 to 3567 m; infrequent; p.

Valeriana edulis Nutt.; CP, DM, and MM to 3599 m; infrequent; p.

Valeriana occidentalis Heller; DM to 3353 m; rare; p.

Violaceae

Viola canadensis L.; BR and TS to 3444 m; rare; p.

Viola nuttallii Pursh; DM to 3414 m; rare; p.

Class Liliopsida

Cyperaceae

Carex albonigra Mack.; CP and MM to ca 3658 m; infrequent; p.

Carex ebenea Rydb.; RI to 3444 m; rare; p.

Carex egglestonii Mack.; DM to 3414 m; rare; p.

Carex elynoides H. T. Holm; CP, DM, MM, and TS at 3353 to 3706 m; common; p.

Carex haydeniana Olney; MM, RI, GB, and BR at 3414 to 3566 m; common; p.

Carex heteroneura W. Boott var. *chalciolepis* (H. T. Holm) F. Hermann; the intergrading var. *epapillosa* F. Hermann also occurs in the range though perhaps not in the alpine; MM and BR to ca 3658 m; common; p.

Carex microptera Mack.; DM (?) to 3414 m; rare; p.

Carex nardina Fries; MM at 3505 m; rare; p.*

Carex nova Bailey; unknown community at ca 3505 m; rare; p.

Carex phaeocephala Piper; CP, DM, MM, and GB to 3566 m; common; p.

Carex rossii F. Boott; DM (?) to ca 3353 m; rare; p.

Juncaceae

***Juncus drummondii* E. Mey.**; RI to 3444 m; rare; p.

***Luzula spicata* (L.) DC.**; MM, WM, and BR to 3627 m; common; p.*

Liliaceae

***Zigadenus elegans* Pursh**; MM, WM, and RI to 3536 m; infrequent; p.*

Poaceae

***Agrostis variabilis* Rydb.**; MM to 3383 m; rare; p.

***Bromus ciliatus* L.**; MM to 3414 m; rare; p.

***Bromus inermis* Leysser**; roadside adjacent to MM at 3487 m; rare; introduced p.

***Calamagrostis purpurascens* R. Br.**; TS to 3414 m; rare; p.*

***Deschampsia cespitosa* (L.) Beauv.**; MM and RI to 3499 m; infrequent; p.*

***Elymus elymoides* (Raf.) Swezey [*Sitanion hystrix* (Nutt.) J. G. Sm.]**; DM to ca 3505 m; rare; p.

***Elymus scribneri* (Vasey) Jones [*Agropyron scribneri* Vasey]**; DM, GB, and TS to 3578 m; common; p.

***Elymus trachycaulus* (Link) Gould [*Agropyron trachycaulum* (Link) Malte]**; DM and MM to 3566 m; common; p.*

***Festuca ovina* L. var. *brevifolia* (R. Br.) Wats.**; CP, DM, MM, GB, BR, and TS to 3706 m; common; p.*

***Phleum alpinum* L.**; MM and RI to 3487 m; frequent; p.*

***Poa arctica* R. Br.**; CP, MM, WM, BR, and TS to 3700 m; frequent; p.*

***Poa fendleriana* (Steudel) Vasey**; DM to 3383 m; frequent; p.

***Poa glauca* Vahl [*P. glauca* ssp. *rupicola* (Nash) W. A. Weber; *P. interior* Rydb.]**; CP, DM, MM, GB, and TS to 3536 m; common; p.*

***Poa nervosa* (Hook.) Vasey**; TS to 3414 m; infrequent; p.

***Poa pattersonii* Vasey**; TS at 3505 m; rare; p.

***Poa pratensis* L.**; MM to 3444 m; rare?; possibly introduced p.*

***Poa reflexa* Vasey & Scribn.**; MM and RI to 3536 m; common; p.

***Poa secunda* Presl [*P. sandbergii* Vasey]**; CP, DM, and TS to 3475 m; frequent; p.

***Stipa lettermanii* Vasey**; DM and MM to 3475 m; frequent; p.

***Trisetum spicatum* (L.) Richter**; CP, MM, BR, and TS to 3700 m; common; p.*

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